Use of pedometers as a tool to promote daily physical activity levels in patients with COPD: a systematic review and meta-analysis

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Pedometer based physical activity promotion as a standalone intervention or alongside pulmonary rehabilitation induces meaningful improvements in daily physical activity levels (steps per day) in patients with COPD. http://bit.ly/2LnxM2o

Cite this article as: Armstrong M, Winnard A, Chynkiamis N, *et al*. Use of pedometers as a tool to promote daily physical activity levels in patients with COPD: a systematic review and meta-analysis. *Eur Respir Rev* 2019; 28: 190039 [https://doi.org/10.1183/16000617.0039-2019].

ABSTRACT The aim of this study was to examine the use of pedometers as a tool to promote daily physical activity levels in patients with COPD.

A systematic review meta-analysis of pedometer physical activity promotion in patients with COPD was conducted. Medline/PubMed, Cochrane Library, Web of Science and CINAHL were searched from inception to January 2019. The search strategy included the following keywords: physical activity promotion, pulmonary rehabilitation and daily physical activity. The eligibility criteria for selecting studies were randomised controlled trials reporting pedometer physical activity promotion in patients with COPD.

Improvements in steps per day were found with pedometer physical activity promotion either standalone (n=12, mean 0.53 (95% CI 0.29–0.77); p=0.00001) or alongside pulmonary rehabilitation (n=7, 0.51 (0.13–0.88); p=0.006). A subgroup analysis reported significant differences in the promotion of physical activity based on baseline physical activity levels and the type of instrument used to assess levels of physical activity.

Future trials should consider the way in which pedometers are used to promote physical activity to inform clinical practice in the setting of pulmonary rehabilitation.

Introduction

Interventions to promote levels of daily physical activity are becoming important in the management of patients with COPD [1, 2]. Studies comparing the levels of physical activity in patients with COPD with healthy age-matched controls have reported significantly lower levels in those with COPD [3–5]. In addition, low levels of physical activity in patients with COPD are associated with an increased risk of hospitalisation and mortality [3, 6, 7]. Therefore, effective approaches to improve daily physical activity are needed in patients with COPD.

This study is registered at www.crd.york.ac.uk/prospero/ with identifier CRD42018103893.

Provenance: Submitted article, peer reviewed.

Received: 04 April 2019 | Accepted after revision: 11 July 2019

Pulmonary rehabilitation has shown substantial improvements in exercise tolerance; however, these findings have not consistently progressed into improvements in daily physical activity [8]. One reason for this may link to physical activity being a complex health behaviour, with the determinants of physical activity influenced by personal, interpersonal, environmental, regional and/or national and global factors [9].

Physical activity promotion through the use of pedometers encompasses the stimulation of patients towards higher levels of daily physical activity by modifying their behaviour, with many versions of this intervention also using elements of the self-regulatory theory [10]. This theory involves a process of guiding an individual's own thoughts, behaviours and feelings towards achieving specific goals [11]. Incorporating the use of pedometers as a real-time feedback tool for improving daily steps allows patients the ability to follow individualised physical activity goals, which can be assessed and improved alongside techniques of motivational interviewing [12].

Implementing behaviour strategies using pedometer feedback can be done a number of ways, including face-to-face contact between patients and clinicians, group contact during rehabilitation sessions and through electronic information and communication technologies (tele-coaching) [13].

Studies have, however, provided inconsistent findings towards the implementation of pedometer-based feedback and motivational interviewing as part of physical activity promotion [14, 15]. Moreover, when the same intervention was added to standard care pulmonary rehabilitation, results remained inconclusive [1]. The most updated systematic review and meta-analysis has found high levels of heterogeneity regarding physical activity promotion, both as a standalone intervention and alongside pulmonary rehabilitation [1]. The existence of such heterogeneity is predominantly due to both methodological variables (types of goal setting, provided feedback and length of intervention) and patient demographics (severity and baseline physical activity levels). Hence, the aim of this systematic review and meta-analysis was to elucidate on aspects of physical activity promotion related to the way that pedometers are used to optimise physical activity in patients with COPD. In this context, we investigated the optimal frequency of goal setting, the type of patient feedback, the optimal length of interventions, the type of instrument used for assessing physical activity, and associations between baseline activity levels and the magnitude of improvement in daily physical activity.

Review objective

The aim of this review was to systematically review and meta-analyse aspects of physical activity promotion, specifically regarding how pedometers are used to optimise physical activity in interventions which incorporate the use of pedometers as a key component for improving levels of daily physical activity in patients with COPD.

Methods

The Cochrane Handbook for Systematic Reviews of Interventions and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [16] guidelines for reporting systematic review and meta-analyses were followed when conducting and reporting this prospectively registered systematic review (identifier CRD42018103893; www.crd.york.ac.uk/prospero/).

Eligibility criteria

The review team conducted a computerised literature search beginning in March 2018 in the following databases: Medline/PubMed, Cochrane Review, Web of Science and CINAHL. The final search of the literature took place on 18 January, 2019. Pre-piloted literature searches prior to the final search strategy were conducted based on two previously published systematic reviews on a related topic [1, 17]. The full search strategy can be found in table 1. It included a wide range of modalities; using terms associated with "chronic obstructive pulmonary disease", "physical exercise training", "physical activity promotion, physical activity counselling" and "randomized controlled trial". Bibliographic details of all articles from the different databases were stored in the reference software file EndNote.

On completion of the literature search, all stored references were exported from EndNote to the systematic review management software programme, Covidence. Eligible studies published in the English language were included if they fulfilled the predetermined PICOS criteria. 1) Population/participants: individuals with COPD defined by spirometry (*i.e.* forced expiratory volume in 1 s (FEV_1)/forced vital capacity (FVC) <0.7). 2) Interventions or exposures: patients with COPD who were enrolled onto a programme of physical activity promotion, which included the use of a tool that provides real-time feedback on steps per day (*i.e.* pedometer screen). This included standalone interventions or those incorporated into pulmonary rehabilitation. 3) Comparison or control groups: patients not receiving any physical activity promotion intervention. 4) Outcomes of interest: the effect of physical activity promotion on steps per day as a

TABLE 1 Search criteria for computerised literature search conducted in PubMed

Search	Query
1	("Chronic obstructive pulmonary disease" [Text Word] OR "COPD" [Text Word] OR "Chronic Lung Disease" [Text Word] OR "Chronic Obstructive Lung Disease" [Text Word] OR "Emphysema" [Text Word] OR "Chronic Bronchitis" [Text Word])
2	("exercise" [Text Word] OR "rehabilitation" [Text Word] OR "exercise training" [Text Word] OR "pulmonary exercise training" [Text Word] OR "physical exercise training" [Text Word] OR "pulmonary rehabilitation" [Text Word] OR "exercise rehabilitation" [Text Word] OR "cardiopulmonary rehabilitation" [Text Word] OR "rehabilitation program#" [Text Word] OR "exercise program#" [Text Word] OR "physical activity advice" [Text Word] OR "physical activity counselling" [Text Word] OR "physical activity promotion" [Text Word] OR "accelerometer#" [Text Word] OR "Pedometer#" [Text Word] OR "activity monitor#" [Text Word] OR "step count#" [Text Word] OR [Text Word] OR "telerehabilitation" [Text Word] OR "e-Health intervention" [Text Word])
3	("Activity" [Text Word] OR "Motor activity" [Text Word] OR "physical inactivity" [Text Word] OR "risk factor" [Text Word] OR "outcome assessment" [Text Word] OR "activity" [Text Word] OR "step#" [Text Word] OR "walk#" [Text Word])
4	(Randomised controlled trial OR clinical trial OR experimental study)
5	1 AND 2 AND 3 AND 4

Text word includes all words and numbers in the title, abstract, other abstract, MeSH terms, MeSH subheadings, publication types, substance names, personal name as subject, corporate author, secondary source, comment/correction notes. #: all terms that begin with specific word.

measure of daily physical activity. 5) Setting: certified research studies. 6) Study design: randomised controlled trials (RCTs), both arms (intervention plus control).

Data extraction

After removing the duplicates and based on the inclusion criteria, two authors (M. Armstrong and N. Chynkiamis) independently and blinded, reviewed the title and abstract of trials and assessed the full text of articles. Any possible disagreement between both authors during the study selection process was discussed with a third author (I. Vogiatzis) for resolution.

For each eligible study, a pre-designed standardised Microsoft Excel form was used to collect data by a single author (M. Armstrong) on the following subheadings: author information (including name of first author and date of publication), blindness, participant characteristics (including age, FEV_1 % pred, FVC, 6-min walk distance (6MWD), baseline daily steps, total lung capacity and residual volume, intervention details, physical activity measurements, primary outcomes and results). Two blinded reviewers (M. Armstrong and N. Chynkiamis) screened all articles independently, any disagreements were sent to a third independent author (I. Vogiatzis) to make a majority agreement.

Quality assessment

Quality assessment was performed using the PEDro quality scale, which is an 11-item scale assessing internal and external validity of clinical trials [18]. Two authors (M. Armstrong and N. Chynkiamis) independently reviewed the following domains employed by this scale: eligibility criteria, random allocation, concealed allocation, baseline similarity, blinding (subject, therapist and assessor), and measures recorded from at least 85% of participants, full intention to treat, group comparison and point measure. The higher the given score, the better the quality. Cut-off points of the scale were excellent (9–10), good (6–8), fair (4–5) and poor (<3) [18].

Data synthesis

Meta-analyses were undertaken using Review Manager (RevMan v.5.3; Cochrane Collaboration, Oxford, UK). Change scores or end of intervention values with the corresponding standard deviation for the outcomes of interest were used to obtain the overall effect size represented by standard mean difference with 95% confidence interval, with a threshold $p<0.05$ considered as significant. Heterogeneity in this meta-analysis was assessed by I^2 value as follows: 0–40%, might not be important; 30%–60%, moderate heterogeneity; 50%–90% substantial heterogeneity; and 75%–100% considerable heterogeneity [19]. A fixed-effects model was used for the meta-analysis; however, if statistical heterogeneity was noted (I^2 >40%), meta-analyses were performed using the random effects model. Sensitivity analysis was used if substantial heterogeneity (I^2 >75%) was reported in meta-analyses.

Results

The search strategy yielded 2582 potentially relevant articles. After removing 714 duplicates and screening 1868 abstract/titles, 55 articles remained for the full-text screening. On completion of full-text screening, 38 studies were excluded. Therefore, 17 studies were considered eligible for inclusion in this systematic review and meta-analysis. One article provided three different comparisons, resulting in three RCTs. A full PRISMA flow diagram of the screening process is shown in figure 1. Participants were individually randomised in all included trials (*i.e.* there were no cluster RCTs). Characteristics of included RCTs are summarised in table 2 and all were published between 2006 and 2018.

Characteristics of included subjects

All of the included trials comprised 1677 patients (45% male), with a median (range) sample size of 72 (16–343). Included patients had a mean (range) age of 66 (54–75) years and average FEV_1 % pred ranged from 43 to 78, indicative of mild-to-moderate COPD [34]. Patients were reported as physically inactive at baseline with an average mean (range) value of 4365 (1557–7161) steps·day^{-1}.

Characteristics of included/excluded trials

A total of 38 studies were excluded from this review on completion of full-text screening. The reasons for exclusion include: the wrong intervention (n=11), duplicates (n=9), wrong study design (n=6), wrong outcomes (n=6), wrong comparators (n=2), no full-text availability (n=2) and no reported data for daily steps (n=2).

Quality assessment

Table 3 provides a summary of the risk of bias decision made for each category for the included studies. In line with the PEDro scale, the quality of included studies ranged from good to excellent (mean (interquartile range) PEDro score 9.29 (1)); suggesting a low risk of bias towards the main outcome measure.

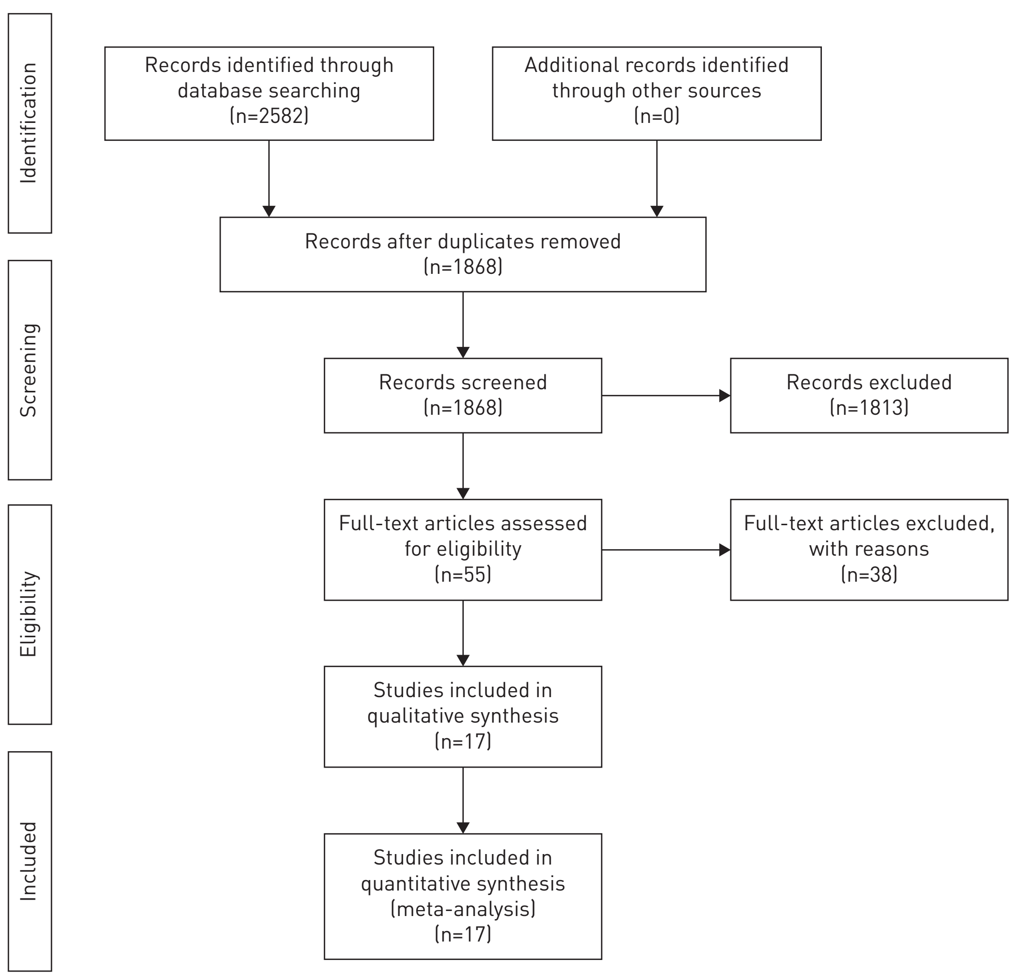

FIGURE 1 PRISMA flow diagram for database search and study selection process.

https://doi.org/10.1183/16000617.0039-2019

TABLE 2 Characteristics of included studies

First author [ref.]	I/C	Age years	FEV$_1$ % pred L	Male/ female	Patient recruitment	Intervention arm	Control arm	Type of feedback	Weekly goals	Time-points/ outcomes
Altenburg [14]	24/24	65 (58–72)	78 (66–95)	32/16	General practices (primary care)	PA counselling 30 min ×5 sessions using MI, GS and pedometer: 12 weeks	Received care appropriate to their health status	Face-to-face	No	3 months/daily steps
Altenburg [14]	23/23	68 (61–72)	58 (40–69)	34/12	Outpatient hospital clinics (secondary care)	PA counselling 30 min ×5 sessions using MI, GS and pedometer: 12 weeks Patients were recruited from outpatient hospital clinics (secondary care)	Received care appropriate to their health status	Face-to-face	No	3 months/daily steps
Altenburg [14]	22/15	54±9.6	43±25.9	32/25	Pulmonary rehabilitation centre	PA counselling (30 min ×5 sessions using MI, GS and pedometer 12 weeks) added to PR 2 h 3 times per week: 9 weeks	PR 2 h 3 times per week: 9 weeks	Face-to-face	No	3 months/daily steps
Arbillaga-Etxarri [20]	220/293	69±9	58±17	448/65	Primary care and 5 hospital care centres	Six components: MI, urban walking training walking, pedometer and personalised calendar, phone updates, exercise leaflet, group walking sessions	General health counselling and info booklet	Remote	No	12 months/ daily steps
Bender [21]	57/58	65±7	54.3±11	48/67	Pulmonary outpatient clinics	Pedometer and personally selected goals involving enjoyed activities of daily living A target of increasing 15% daily steps per month for 3 months	Pedometer with no goal setting or communication about physical activity. A small 1-1 telephone call to communicate daily steps	Remote	No	3 months/daily steps
Cruz [15]	16/16	66.5±8.4	66.9±20.1	27/5	3 primary care centres and a district hospital	PA-focused behavioural counselling (average 25 min ×8 sessions using SCT, SE, MI and pedometer and diary feedback: 6 months) added to PR (1 h 3 times per week ET and 1.5 h once a week EDU session: 3 months)	PR (1 h 3 times per week ET and 1.5 h once a week EDU session: 3 months)	Face-to-face	Yes	3 months/daily steps
De Blok [22]	172/171	67±8	56±20	219/124	N/A	Lifestyle PA counselling (3 min ×4 sessions using MI, GS and pedometer: 9 weeks) added to PR (9 weeks)	PR (9 weeks)	Face-to-face	No	9 weeks/daily steps
Demeyer [13]	172/171	67±8	56±20	219/124	6 rehabilitation centres across Europe	Received the usual care plus the tele-coaching platform This includes a one-to-one interview, a step counter and smartphone coaching application	Received a standard leaflet explaining the importance of PA in COPD as well as information about PA recommendations	Remote	Yes	3 months/daily steps
Holland [23]	80/86	69±11	50±19	99/67	Pulmonary rehabilitation waiting list	Home rehabilitation, which involved a pedometer and 7-weekly structured telephone calls based around motivational interviewing to improve walking fitness	Centre-based rehabilitation with encouragement to exercise at home, no pedometer issued	Remote	No	12 months/ daily steps
Horrnix [24]	15/15	67±7	43±17	17/13	Hospitalised exacerbation patients	Pedometer worn with telephone calls three times per week for 1 month to motivate and stimulate patients to increase their PA levels	No contact and didn't received any motivational messages, just advice about increasing PA before hospital discharge	Remote	Yes	1-month, daily steps

Continued

https://doi.org/10.1183/16000617.0039-2019

TABLE 2 Continued

First author [ref.]	I/C	Age years	FEV$_1$ % pred L	Male/ female	Patient recruitment	Intervention arm	Control arm	Type of feedback	Weekly goals	Time-points/ outcomes
Hospes [25]	18/17	62±8	64±15	21/14	Outpatient clinic	12-week customised exercise counselling to enhance daily physical activity Based on principles of goal setting and implementation of goals	No counselling programmes	Face-to-face	No	3 months/daily steps
Kawagoshi [26]	12/15	75±9	59.3±22	24/3	N/A	Home-based rehabilitation in addition to monitored daily physical activity using pedometer and received monthly feedback on physical activity levels	Multidisciplinary home-based PR programme for 12 months	Face-to-face	No	12 months, daily steps
Mendoza [27]	52/50	68±8	66±19	62/40	Outpatient clinics at private and public hospitals	Received pedometer and physical activity diary alongside counselling to improve physical activity	Received counselling at each visit to increase their physical activity levels and advised to walk for at least 30 min per day	Face-to-face	No	3 months/daily steps
Moy [28]	154/84	66±9		223/15	National Database of Veterans	Pedometer and access to a website with components including; step count feedback, weekly goals, motivational content to enhance activity levels	Wore pedometer and recorded steps. Received no instruction about exercise and were not assigned step goals or website	Remote	Yes	4 months/daily steps
Nolan [29]	76/76	69.0±9.0	50.5±21.2	110/42	Hospital-based PR unit	Lifestyle PA counselling (30 mins ×8 sessions using GS and pedometer: 8 weeks) added to PR (1 h ×2 times per week: 8 weeks)	PR (1 h ×2 time per week: 8 weeks)	Face-to-face	Yes	9 weeks/daily steps
Tabak [30]	14/16	66±7	52±13	19/11	Hospital clinic	Tele-rehabilitation intervention for 4 weeks	Received no tele-rehabilitation Usual care was defined as usual medication/physiotherapy	Remote	Yes	1 month/daily steps
Varas [31]	21/19	67±8	49±16	31/9	Pulmonology consultants	5 group physiotherapy sessions, 8 weeks counselling to increase daily activity levels, through telephone meetings	Informative sessions on the benefits of exercise, pedometer issued but no additional support	Remote	Yes	8 weeks/daily steps
Vorrnik [32]	84/73	62±9	55±17	78/79	Outpatient physiotherapy practises	Consisted of two compartments: 1) smartphone application; 2) physiotherapist-based website for providing real-time goals and feedback for 6 months	No intervention	Remote	Yes	3 months/daily steps
Wan [33]	57/52	68±8	61±21	95/14	General pulmonary clinics	Pedometer and received access to a website which provided four key components; individualised goal setting, iterative step-count feedback, motivational content and online community forum for 3 months	Received a pedometer and written material about exercise but weren't assigned step-count goals	Remote	Yes	3 months, daily steps

Data are presented as n, mean±SD or mean (range). FEV$_1$: forced expiratory volume in 1 s; PA: physical activity; N/A: not applicable; PR: pulmonary rehabilitation; MI: motivational interviewing; GS: goal setting; SCT: social cognitive theory; SE: self-efficacy; ET: exercise training; EDU: education.

https://doi.org/10.1183/16000617.0039-2019

TABLE 3 Qualitative synthesis of included studies using PEDro scale for the quality of randomised controlled trials

First author [ref.]	Eligibility criteria	Random allocation	Concealed allocation	Baseline similarity	Blinding (subject)	Blinding (therapist)	Blinding (assessor)	Measure >85%	ITT	Group comparison	Point measure	Quality score
Altenburg [14]	*	*	*	*				*	*	*	*	8
Arbillaga-Etxarri [20]	*	*	*	*	*	*			*	*	*	9
Bender [21]	*	*		*				*	*	*	*	7
De Blok [22]	*	*		*		*		*	*	*	*	8
Cruz [15]	*	*	*	*	*		*	*	*	*	*	10
Demeyer [13]	*	*	*	*			*	*	*	*	*	9
Holland [23]	*	*	*	*			*	*	*	*	*	9
Horrnix [24]	*	*		*				*	*	*	*	7
Hospes [25]	*	*		*				*	*	*	*	7
Kawagoshi [26]	*	*		*			*	*	*	*	*	8
Mendoza [27]	*	*		*			*	*	*	*	*	8
Moy [28]	*	*	*	*				*	*	*	*	8
Nolan [29]	*	*	*	*		*	*	*	*	*	*	10
Tabak [30]	*	*	*	*				*	*	*	*	8
Varas [31]	*	*		*	*			*	*	*	*	8
Vorrnik [32]	*	*	*	*			*	*	*	*	*	9
Wan [33]	*	*	*	*			*	*	*	*	*	9

ITT: intention to treat. *: yes, score=1. The higher the given score, the better the quality. Cut-off points of the scale were: excellent (9–10), good (6–8), fair (4–5) and poor (3).

Meta-analyses of included studies

When observing the effects of physical activity promotion, there was a positive effect on steps per day compared with usual care (n=12 RCTs; 0.53 (0.29–0.77), p<0.00001) (figure 2) [13, 14, 20, 21, 24, 25, 27, 28, 30, 32, 33], which equated to an improvement of ~1000 steps·day^{-1}. A positive effect on steps per day was also found when pedometer physical activity promotion was added to pulmonary rehabilitation *versus* pulmonary rehabilitation alone (n=7 RCTs; 0.51 (0.13–0.88), p=0.006) (figure 2) [14, 15, 22, 23, 26, 30, 31]. However, the pooled analysis of pedometer physical activity promotion compared with usual care reported considerable heterogeneity (I^2=77%).

Moreover, the increases in daily physical activity induced by pedometer physical activity promotion (both alone and alongside pulmonary rehabilitation), were comparable among studies that provided: 1) weekly or infrequent goal setting; 2) an intervention length <3 months or >3 months; and 3) remote or face-to-face contact following overall or subgroup analysis (all p<0.05) (table 4). In contrast, studies employing accelerometers to measure physical activity were less effective compared with those employing pedometers. Furthermore, patients with greater baseline physical activity levels (>4000 steps·day^{-1}) exhibited greater improvements in daily physical activity compared with those with lower baseline physical activity levels (<4000 steps·day^{-1}) (table 4).

Sensitivity analysis removing a single study [27] from the pooled analysis of pedometer-based physical activity promotion reduced heterogeneity (I^2=60%). The sensitivity analysis did not statistically affect the pooled analysis of the remaining 11 studies in pedometer-based physical activity promotion (0.44 (0.25–0.63); p<0.05).

Discussion

Summary of the main findings

This systematic review and meta-analysis of 19 RCTs provides evidence that pedometer physical activity promotion as a standalone intervention compared with usual care or alongside pulmonary rehabilitation

Study or subgroup	Activity promotion			Usual care				Standard mean difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total	Weight %	
Pedometer PA alone								
Altenburg [14]	579	3296	24	−27	2970	24	7.2	0.19 (−0.38–0.76)
Arbillaga-Etxarri [20]	816	2852	88	65	2427	145	10.5	0.29 (0.02–0.55)
Altenburg [14]	931	8312	23	−64	8463	23	7.0	0.12 (−0.46–0.70)
Bender [21]	1114	1907	57	−305	1727	58	9.2	0.78 (0.40–1.15)
Demeyer [13]	870	2020	172	−687	1763	171	10.9	0.82 (0.60–1.04)
Horrnix [24]	984	1926	15	1013	821	15	5.8	−0.02 (−0.73–0.70)
Hospes [25]	785	2537	18	−1367	2367	17	5.9	0.86 (0.16–1.55)
Mendoza [27]	9080	1983	52	138	1649	50	8.4	1.60 (1.15–2.05)
Moy [28]	744	1817	154	−346	1949	84	10.4	0.44 (0.17–0.71)
Tabak [30]	−163	610	13	−639	547	16	5.4	0.80 (0.04–1.57)
Vornik [32]	−593	1830	84	−833	1631	73	10.0	0.14 (−0.18–0.45)
Wan [33]	441	1547	57	−105	1551	52	9.2	0.35 (−0.03–0.73)
Subtotal (95% CI)			**757**			**728**	**100**	**0.53 (0.29–0.77)**
Heterogeneity: Tau^2=0.12; Chi^2=47.43, df=11 (p<0.00001); I^2=77%								
Test for overall effect: Z=4.39 (p<0.0001)								
Pedometer PA promotion + PR								
Altenburg [14]	1862	6216	22	184	4660	15	14.0	0.29 (−0.37–0.95)
Cruz [15]	3279	2805	13	−187	1770	13	10.5	1.43 (0.55–2.31)
De Blok [22]	1430	31106	8	455	2177	8	9.1	0.34 (−0.65–1.33)
Holland [23]	520	2526	80	−160	3558	86	21.2	0.22 (−0.09–0.52)
Kawagoshi [26]	3540	4395	15	849	1760	12	11.8	0.75 (−0.04–1.54)
Nolan [29]	727	6792	76	892	5173	76	20.9	−0.03 (−0.35–0.29)
Varas [31]	3158	2191	17	−16	2795	16	12.4	1.24 (0.48–1.99)
Subtotal (95% CI)			**231**			**226**	**100**	**0.51 (0.13–0.88)**
Heterogeneity: Tau^2=0.15; Chi^2=17.93, df=6 (p=0.006); I^2=67%								
Test for overall effect: Z=2.63 (p=0.009)								
Test for subgroup differences: Chi^2=0.01, df=1 (p=0.90), I^2=0%								

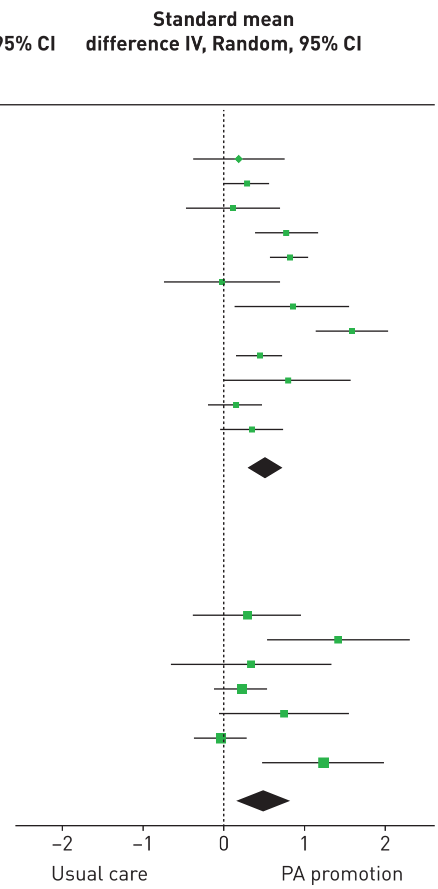

FIGURE 2 Effect sizes of pedometer-based physical activity (PA) promotion on steps per day in patients with COPD. PR: pulmonary rehabilitation.

TABLE 4 Subgroup analysis on physical activity (PA) outcomes of included studies

Subgroups	Overall analysis				Pedometer PA alone				Pedometer PA promotion + PR			
	n	Effect size		I^2 %	n	Effect size		I^2 %	n	Effect size		I^2 %
		SMD	95% CI			SMD	95% CI			SMD	95% CI	
Goal setting												
Weekly	9	0.50	0.21–0.78	77	6	0.44	0.16–0.71	70	3	0.82	−0.23–1.88	88
Infrequent	10	0.55	0.24–0.85	75	6	0.64	0.19–1.09	84	4	0.29	0.04–0.54	0
Duration												
<3 months	15	0.57	0.31–0.84	78	10	0.57	0.27–0.88	79	5	0.60	0.00–1.20	76
>3 months	4	0.34	0.18–0.50	0	2	0.36	0.17–0.55	0	2	0.35	−0.10–0.80	34
Type of feedback												
Remote	10	0.47	0.27–0.67	68	8	0.46	0.24–0.68	67	2	0.67	−0.32–1.66	83
Face-to-face	9	0.60	0.14–1.06	81	3	0.70	−0.06–1.46	86	5	0.48	−0.03–0.99	65
Measure of PA												
Accelerometer	8	0.38	0.09–0.67	79	4	0.36	−0.03–0.75	83	4	0.44	−0.04–0.91	74
Pedometer	11	0.64	0.35–0.92	69	8	0.64	0.31–0.97	75	3	0.63	0.00–1.26	48
Baseline PA levels												
Low baseline PA	7	0.32	0.10–0.53	51	4	0.46	0.21–0.70	36	3	0.11	−0.10–0.33	0
High baseline PA	11	0.67	0.36–0.98	80	8	0.59	0.24–0.94	83	3	0.95	0.22–1.67	63

PR: pulmonary rehabilitation; SMD: standard mean difference.

compared with pulmonary rehabilitation alone improves steps per day by a magnitude that is within the minimal important difference (MID) of 600–1100 steps·day $^{-1}$ reported by DEMEYER *et al.* [35] (table 3). Moreover, this meta-analysis suggests that pedometer physical activity promotion was more effective in patients with greater baseline physical activity levels and when pedometers were used to measure improvements in physical activity compared with accelerometers (table 4).

The addition of a sensitivity analysis reducing levels of heterogeneity provided no additional effects to the pooled analysis of pedometer physical activity promotion.

Interpretation of the results

Previous literature surrounding the effects of physical activity promotion has reported inconclusive evidence of the effectiveness of this intervention on steps per day. In agreement with the findings of our review, QUI *et al.* [1] found that physical activity promotion improved steps per day compared with usual care in nine studies. However, significant heterogeneity (I^2=81%) may have affected the overall analysis of those studies. The increase in steps per day reported as a result of pedometer physical activity promotion seems much larger than those from other methods including exercise training as part of pulmonary rehabilitation, health monitoring, long-term oxygen therapy or neuromuscular electrical stimulation [12, 17].

However, LAHHAM *et al.* [17] reported that physical activity promotion was not an effective standalone intervention towards improving steps per day. A number of disparities are apparent between review articles. First, LAHHAM *et al.* [17] based their analysis of physical activity promotion on a subgroup analysis of subjective and objective measures. Both our study and that of QUI *et al.* [36] only included studies reporting objective measures of daily physical activity due to limited validity and inaccuracy of subjective measures of activity levels in patients with COPD [37]. Secondly, the number of included studies varied across separate meta-analyses. In our review, a total of 12 studies with an average total sample size of 120 were included in the pooled analysis of pedometer physical activity promotion. Meanwhile, LAHHAM *et al.* [17] reported only two studies on objective measures of physical activity, with an average total sample size of 17. With the significant benefits of collecting and reporting objective measures of physical activity in both healthy individuals and patients with COPD, and a much greater sample size across pooled analyses, our review and that of QUI *et al.* [1] could be argued to have more valid findings for patients with COPD than LAHHAM *et al.* [17]. Benefits of pedometer physical activity promotion have also been reported in patients with type 2 diabetes [36]. A meta-analysis including 11 RCTs reported a significant increase in physical activity with an average magnitude of improvement of 1822 steps·day $^{-1}$, which is greater than we found in patients with COPD (figure 3).

When observing the effects of physical activity promotion alongside pulmonary rehabilitation, the present study and that by LAHHAM *et al.* [17] and QUI *et al.* [1] have shown statistically significant effects on steps per day. LAHHAM *et al.* [17] stated that providing persistent and individualised feedback on activity levels in

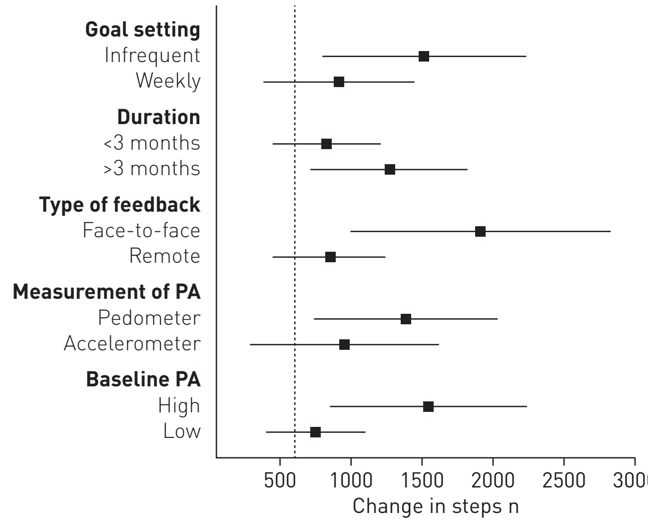

FIGURE 3 Comparison between improvements in daily steps shown by various implementation modalities. Vertical dashed line indicates the lower levels of minimal important difference in patients with COPD. PA: physical activity.

conjunction with pulmonary rehabilitation, achieved significant effects that exceeded both physical activity promotion alone and pulmonary rehabilitation alone. However, Lahham *et al.* [17] were unable to include a recent RCT [29]. Within that study, the authors reported evidence questioning the effectiveness of physical activity promotion on daily physical activity in patients attending pulmonary rehabilitation [29]. It was determined that the routine use of this intervention should not be included in standard care pulmonary rehabilitation because levels of daily physical activity were greater after pulmonary rehabilitation alone when compared with baseline measures [29]. These results were based upon this study being the first to include a large sample size, suggesting other studies were underpowered. In addition, that study [29] scored highly on the PEDro scale, suggesting it had a low level of bias and the results reported were of high quality. The present study and that by Qui *et al.* [1] have been able to incorporate the study by Nolan *et al.* [29] into separate meta-analyses. A contrast in reporting physical activity between our study and that by Qui *et al.* [1] has provided two interpretations of the study by Nolan *et al.* [29]. Qui *et al.* [1] provided accelerometer step counts from baseline as a measure of steps per day from the study by Nolan *et al.* [29], reporting a small positive effect on physical activity levels. In contrast, we have chosen to report steps per day from pedometer step counts, resulting in a neutral effect on physical activity. We agree with Qui *et al.* [1] that accelerometers provide a more accurate measure of physical activity; however, the majority of studies in our meta-analysis have primarily used pedometers to report physical activity levels, so this may falsify results [29].

Our meta-analysis also suggests a number of important principles surrounding the way in which pedometers have been used for promoting physical activity. An overall analysis of patients with greater baseline physical activity levels (>4000 steps·day $^{-1}$) showed greater improvements in steps per day compared with those with lower baseline physical activity (⩽4000 steps·day^{-1}) (figure 3). Of further interest is the influence that baseline physical activity had on the effects of pedometer physical activity promotion alongside pulmonary rehabilitation (table 4). In studies that implemented physical activity promotion alongside pulmonary rehabilitation, an insignificant effect on steps per day was reported when patients had a baseline physical activity ⩽4000 steps·day $^{-1}$ [14, 15, 31]. It must be outlined that there was only a small number of studies in this subgroup analysis with a small mean sample size; however, such differences in effect size warrants closer scrutiny.

Osadnik *et al.* [38] proposed that patients with COPD who exhibit greater exercise capacity prior to pulmonary rehabilitation are more likely to achieve greater improvements in daily physical activity. They reported clinically meaningful improvements in steps per day with patients reporting a 6MWD >350 m compared with <350 m (707±1780 *versus* 157±1694 steps·day $^{-1}$). This higher likelihood of improvement in physical activity in patients preserving a greater exercise tolerance may also provide an explanation for those patients exhibiting a higher baseline physical activity. However, in contrast with this notion, a recent study from Gulart *et al.* [39] suggests that patients with lower values of FEV_1 and steps per day were more likely to achieve MID in steps per day. This finding was attributed to the notion that patients with more severe disease have a greater potential for improvement as they are further from their "maximal" capacity, compared with patients with less severe disease.

In addition, our meta-analysis has found that the primary measure of physical activity (*i.e.* through accelerometers or pedometers) may have marked influences on the effects of physical activity promotion (table 4).

Specifically, significant improvements in steps per day were shown in those studies reporting physical activity *via* a pedometer compared with an accelerometer (figure 3). The finding in physical activity outcomes may be due to accelerometers being a validated tool for measuring steps per day in patients with COPD and therefore pedometers may overestimate physical activity [40]. However, a number of previous studies, including Qui *et al.* [1], disagree with this finding. Both that study [1] and a meta-analysis in patients with type 2 diabetes [41] have shown no significant differences between accelerometers and pedometers. Consideration must be made in relation to these comparisons being indirect, with such confirmation potentially required through a future 1 *versus* 1 design.

In contrast, pedometer physical activity promotion in patients with type 2 diabetes presents different findings. For instance, it has been reported that patients with type 2 diabetes should initially set their own activity goals, before they set to increase their goals with the assistance of healthcare professionals [36]. We were unable to confirm this hypothesis among patients with COPD as many of the reported studies do not provide definitive step goal descriptions. In addition, studies have shown that the use of step diaries alongside pedometers as a source of motivation were imperative to increase physical activity levels [36, 42, 43].

Finally, it has become evident that regardless of the way pedometers are used (*i.e.* frequency of goal setting, type of patient feedback, length of intervention, the instrument used to assess physical activity) or the baseline activity levels, the improvement in steps per day is within the MID (figure 3) [35]. This finding has strong implications for the use of pedometers as part of the comprehensive management of patients with COPD.

Quality of the evidence

The overall quality of evidence from included studies was good, in line with the PEDro scale for quality assessment. The inability to blind subjects reduced the overall quality of evidence and increased the risk of bias towards the intervention procedure and may increase the chances of a placebo effect when using the pedometer. Future research reporting the effects of physical activity promotion may improve quality scoring by blinding all subjects from the intervention procedure. However, a concern remains that blinding patients from the intervention would require a pedometer being issued to a control group, which may present the control group with a level of physical activity promotion as they are able to monitor their daily steps. A number of studies were unable to blind any members of the study from patient allocation [14, 21, 24, 25, 28, 30]. In any clinical trial, blinding of at least the researcher is desirable and the blinding of subjects is warranted in order to decrease bias within the findings. When blinding is not used or the subject group status is easily detectable, subjects will generally try to fulfil the perceived expectation of the researcher [44].

Strength and limitations

This systematic review and meta-analysis is the first to include two recently published RCTs reporting pedometer-based physical activity promotion implemented either alone [20] or alongside a combined pulmonary rehabilitation programme [31]. Moreover, we are the first to report that, regardless of how pedometers are used in the implementation of physical activity promotion, they can provide improvements in daily physical activity (steps per day) which exceed the MID. Several limitations should be noted. First, some heterogeneity existed in the outcomes of pedometer physical activity promotion, which was partially explained by our findings on the modalities of pedometer use. Secondly, we cannot be certain of the specific improvement a pedometer intervention can have alongside pulmonary rehabilitation on daily physical activity without knowing the exact progression of exercise training for individual patients during pulmonary rehabilitation. Finally, despite a comprehensive search of the literature using the main scientific search databases, there is still a possibility that studies eligible for inclusion may have been missed. The search restriction on English written studies and the failure to search for unpublished studies and/or abstracts/conference papers may have resulted in selection and publication bias.

Conclusion

In conclusion, our systematic review and meta-analysis provides evidence that pedometer-based physical activity promotion promotes steps per day when it is used as an intervention alone or alongside pulmonary rehabilitation, including two recently published RCTs [20, 31]. Future trials should concentrate on high-quality study designs, with specific thought towards the optimal way of using pedometers during physical activity promotion (*i.e.* consider frequency of goal setting, type of patient feedback, length of intervention and instrument used for assessing physical activity). This review has found further evidence that patients benefit more from physical activity promotion when baseline levels of physical activity are >4000 steps·day^{-1}. Therefore, consideration of baseline daily physical activity levels and/or exercise tolerance [38], should feature prominently in future studies. Furthermore, future studies should investigate the combined benefits of pulmonary rehabilitation, physical activity promotion and cognitive behavioural therapy for those patients with severe COPD who are anxious and depressed and therefore exhibit limitations in improving daily physical activity. Moreover, future studies could incorporate the addition of semi-automated tele-coaching as delivered by Demeyer *et al.* [7], as a low maintenance approach to providing continued support towards daily physical activity feedback [38].

Author contributions: M. Armstrong conducted the study, collected and analysed the data, and wrote the manuscript. N. Chynkiamis supported the collection of data. I. Vogiatzis, A. Winnard, S. Boyle and C. Burtin contributed to the review/editing of the manuscript. All authors read and approved the final manuscript.

Conflict of interest: None declared.

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